

NETWORKED AND FIELD ADDRESSABLE DISTRIBUTED ANTENNA SYSTEM

BACKGROUND

(1) Technical Field

5 The present invention is related to the field of wireless RF or optical communications and information (data) networking. More specifically, the present invention provides an apparatus and a method for providing a networked and field addressable distributed antenna system for facilitating broadband wireless communications.

10 (2) Brief Discussion of Prior Art

As data processing continues to advance, the number and types of data processing applications are steadily increasing. In recent years, for example, it has become possible to use computer systems for the storage and playback of digital audio and video.

15 Contemporaneously with increases in processing speed, computer networking has become extremely important for communicating between data processing applications.

With ever-evolving communication networks such as the Internet and data delivery systems such as cable and satellite television, which provide users with rich information content, faster and faster inter-computer connections are required.

20 Presently, most high-speed connections in the range of megabit per second (Mbps) and up rely on either physical connections such as wires or fiber optic connections, or on point-to-point RF wireless connections with very limited range. A need presently exists for a wireless network which allows for coverage of a selective area inside of a larger

megacell service area. The present invention proposes techniques and methods incorporating field distributed short-range repeater nodes that are networked in order to repeat a signal along a desired and dedicated path to a particular picocell within the megacell service area.

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SUMMARY

The present invention provides techniques and methods incorporating field distributed short-range repeater nodes that are networked, in order to repeat a signal along a desired and dedicated path to a particular picocell within a megacell service area.

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One embodiment of the present invention provides a networked and field addressable distributed antenna system comprising a large field megacell coverage area. A portion of the coverage area is partitioned into a plurality of short-range picocells. Each of the picocells is serviced by a secondary base repeater node, which is operative to receive an information signal from a neighboring secondary base repeater node or from an originating information signal source. In addition, each picocell receives a command signal, including a direction command from an originating base station having a command signal transmitter. Further, the picocells transmit the information signal in at least one of three directions for receipt by local users or for use by a neighboring secondary base repeater node, which is ideally, positioned along the direction to which the information signal was transmitted. The direction in which the information signal is transmitted is determined by the direction command of the command signal. The

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secondary base repeater nodes may be positioned such that they re-broadcast the information signal to neighboring secondary base repeater nodes in a tree structure.

In another embodiment the present invention provides a networked and field addressable distributed antenna system, wherein a networked and field addressable distributed antenna system is utilized. According to this embodiment, at least a portion of the secondary base repeater nodes are further configured to modify a received information signal and to re-transmit the received information signal as a modified information signal.

In yet another embodiment the present invention provides a networked, field addressable distributed antenna system. According to this embodiment, the secondary base repeater nodes further include a command signal receiver for receiving a command signal and an information receiving antenna for receiving the information signal from a neighboring, secondary base repeater node, or from an originating information signal source. Further, this embodiment of the invention provides an amplifier for receiving the information signal from the information-receiving antenna, wherein the antenna is configured to amplify the information signal. An information signal transmitter is provided and is configured to receive the amplified information signal from the amplifier and, in response to the command signal, the information signal transmitter transmits the information signal to at least one of three picocells. The direction in which the information signal is transmitted is determined by the direction command of the command signal.

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Yet another embodiment of the present invention provides a secondary base repeater node for use within a networked, field addressable distributed antenna system. The secondary base repeater node includes a command signal receiving antenna, an information receiving antenna, an amplifying means connected with the information receiving antenna, a three-directional information signal transmitting antenna, a switch bank connected between the amplifying means and a three-directional information signal transmitting antenna. Wherein the transmitting antenna, in conjunction with the command signal receiver, is configured to receive the direction command from the command signal, and to selectively cause the three-directional information signal transmitting antenna to re-transmit the amplified information signal in at least one of three directions based on the direction command.

Another embodiment of the present invention provides an originating base station, which operates within a networked and field addressable distributed antenna system. According to this embodiment, the originating base station comprises a code generating transmission unit including a direction code database. The database includes direction codes for each switch controlling the three-directional information signal transmitting antennas.

Additionally, the invention provides a processor for determining a signal path. This processor includes a plurality of secondary base repeater nodes, and a means for retrieving digital direction codes from the direction code database corresponding to switches controlling the three-directional information-signal transmitting antennas along the path. Further this embodiment of the invention provides modulator for receiving the digital direction codes from the processor and for using an amplitude-modulation scheme

to modulate the digital direction codes onto a radio frequency channel, thus producing a command signal. This command signal is then transmitted to a plurality of secondary base repeater nodes.

5 Yet another embodiment of the present invention provides method for distributing information to selective picocells within a megacell by using a networked and field addressable distributed antenna system. According to this method, an information signal is received from an information source at a secondary base repeater node. Next, a command signal, including a direction command from a command signal transmitter, is
10 received, and the protocol determines at least one direction which to re-transmit the received information signal, which originated with the secondary base repeater node. The signal is re-transmitting in at least one of three directions.

BRIEF DESCRIPTION OF THE DRAWINGS

15 These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. 1 is an illustrative diagram depicting a path through a megacell via a plurality of
20 picocells;

FIG. 2 is an illustrative diagram depicting a fan-out tree structure embodiment, along with an information signal output end receiver and a loop back means;

FIG. 3 is a block diagram depicting the components of a secondary base repeater node;

FIG. 4(a) is a block diagram depicting the architecture of an amplitude-modulated frequency shift keying modulator for transmitting a multi-bit wide command signal in digital binary segments;

FIG. 4(b) is a block diagram depicting the architecture of an amplitude-modulated frequency shift keying demodulator for receiving and detecting a multi-bit wide command signal in digital binary segments;

FIG. 4(c) is a waveform diagram depicting a typical amplitude-modulated frequency shift keyed signal;

FIG. 5 is a block diagram depicting the architecture of a typical originating base station; and

FIG. 6 is a flow diagram depicting the steps in the method of the present invention.

DETAILED DESCRIPTION

The present invention is related to the field of communications and data networking.

More specifically, the present invention provides an apparatus and method for providing a networked and field addressable distributed antenna system for facilitating broadband wireless communications. The following description is presented to enable one of ordinary skill in the art to make and use the invention and to incorporate it in the context of particular applications. Various modifications, as well as a variety of uses in different applications will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to a wide range of embodiments. Thus, the present invention is not intended to be limited to the embodiments presented, but is to be

accorded the widest scope consistent with the principles and novel features disclosed herein.

In order to provide a working frame of reference, first a glossary of terms used in the description and claims is given as a central resource for the reader. Then, a brief introduction is provided in the form of a narrative description of the present invention to give a conceptual understanding prior to developing the specific details.

Glossary

Before describing the specific details of the present invention, it is useful to provide a centralized location in which selected terms used herein and in the claims are defined. The terms defined herein are intended to assist the reader in gaining a feel for the words used herein, and not to imply their entire scope or absolute limitations to them as they apply to the invention described herein. The terms defined are as follows:

Antenna – An antenna is any mechanism for converting a wire (metal, fiber optic, etc.) based signal into a wireless signal (RF, laser, etc.).

Broadband – Broadband refers traditionally to signals of higher bit-rate and bandwidth than necessary for transmitting digitized voice signals (around 64 kilobits per second). Typically, broadband signal transmissions are used in short-range, line-of-sight architectures. Examples of RF channels that may be used in conjunction with the present

invention for broadband communication include the 30, 40, 60, and 90 GHz millimeter wave bands as well as optical wireless and laser communication technologies.

Command Signal – A command signal, as used with the present invention, is a signal

5 which controls switches at a secondary base repeater node in order to select the direction(s) in which an information signal received at the secondary base repeater node will be retransmitted. Preferably, the command signal is a multi-bit wide direction command transmitted by amplitude modulating and phase shifting command segments onto a radio frequency carrier channel at an originating base station for detection and reassembly in a register at each of the secondary base repeater nodes in the megacell.

10 The multi-bit direction command provides a path setup through a plurality of secondary base repeater nodes to at least one desired picocell using a database of switching control codes for the three-directional information transmitting antennas of the secondary base repeater nodes.

15 Information Signal – The information signal is a data signal transmitted through the nodes in the megacell from secondary base repeater node to secondary base repeater node as a broadband signal. The information signal could, for example, comprise digitized audio, video, or text, or other type of information or may be an analog information signal.

20 Local – The term local indicates point-to-point communication between a user within a picocell and the secondary base repeater node servicing that picocell. More generally, local may also indicate a communication that takes place within a picocell (e.g.,

communication between neighboring secondary base repeater nodes may be considered local).

Megacell – A megacell is a large physical area serviced by a plurality of secondary base
5 repeater nodes. The megacell may be any size and shape (typically many kilometers
across) depending on the particular application, and is generally too large to be serviced
by a single originating input end base or single secondary base repeater node. The
megacell is divided into many side-by-side short range picocells, a desired portion of
which may be serviced by setting up communication paths among the secondary base
10 repeater nodes.

Narrowband – A narrowband channel is used for transmission of the command signal.
The narrowband signal preferably has an effective communication range great enough to
reach all of the secondary base repeater nodes in the megacell (megacell distribution).

15 Narrowband channels are typically for low bit-rate communication (around 64 kilobits
per second), and are effective for long-range line-of-sight and non-line-of-sight
communications among distributed nodes. Typical examples of narrowband channels
include cellular and personal communication systems (PCS) channels common in today's
wireless communication systems.

20 Neighboring – The term neighboring is generally used to indicate communications
occurring in a point-to-point fashion between adjacent cells, e.g., between secondary base
repeater nodes across a picocell without the need for repeating the signal.

Picocell – Picocells are short range, small subdivisions of a megacell. Each picocell within a megacell in which service is desired is serviced by a secondary base repeater node. Picocells are generally in the neighborhood of 50 to 500 meters across, depending on the channel data rates used for broadband communications and the needs of a particular embodiment.

Tree Structure – A tree structure is a well-known geometric networking structure which begins at a root or origin and branches outward to terminate at leaf nodes. For purposes of the present invention, each node in the tree structure preferably has three sub-branches (e.g., each secondary base repeater node services the following three picocells, each with a receiving secondary base repeater node for receiving the information signal transmitted across the respective picocell from an originating secondary base repeater node).

Depending on the needs of the particular embodiment, the tree structure of the secondary base repeater nodes (and hence, the picocells) within a megacell may be balanced or non-balanced (e.g., may have the same number of sub-branches at each node).

User – Users within the megacell are typically defined as data applications receiving and using the data contained in the broadband information signal.

Introduction

In general terms, the present invention provides a mechanism, technique, and method which uses networked and field addressable distributed antennas in order to provide

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broadband coverage in a megacell subdivided into a plurality of picocells. Secondary
base repeater nodes are distributed throughout the megacell such that each secondary
base repeater node can receive an information signal, which it can re-transmit in at least
one of three directions. The information signal is transmitted on a broadband channel
5 and propagates in a tree-like manner across the megacell. The direction(s) in which the
information signal is transmitted from each secondary base repeater node is determined
by a control signal transmitted from a control signal transmitter on a narrowband channel.
In order to generate the control signal, a database is used, which stores control codes for
switches that control the direction in which the information signal is transmitted from
10 each secondary base repeater node. The control codes are used in order to guide an
information signal along a desired path in the megacell so that it reaches a desired
picocell.

Details of the Present Invention

15 The present invention provides a field addressable distributed antenna system for
networked wireless communication systems, and suitable for many military and
commercial broadband applications. Multiple directive and short-range distributed
antennas are interconnected and networked using relay and repeater nodes.

Communication link and signal routing to a local picocell is established via matching
20 digital switching codes, transmitted independently, along with an information signal to be
routed. An information signal can be addressed to reach one or many of the "local"
nodes in an array of multiple networked antennas. The nodes communicate in a tree
topology of two or more short range cells (Pico-cells), each receiving the signal from a

higher level (in the tree) and passing it (if instructed) to lower branches in the commanded direction or by the selected antenna beam. The networked base antenna system operates mainly in broadcast mode (mono and multicast) for area coverage, but can also operate in a bi-directional communications mode utilizing a loop back means.

- 5 The proposed architecture is scalable and can be implemented in one or more of the RF, microwave, and millimeter wave bands, as well as in the optical wireless and laser communication domain with equal and common functionality.

An illustrative diagram depicting a path through a megacell is presented in **FIG. 1**. A megacell **100** is divided into a plurality of picocells **102**. Although not shown, the whole megacell **100** may be divided into multiple picocells **102**. Only the picocells used for transmission of an information signal to a desired target picocell **104** are shown.

Generally, each picocell **102** is serviced by a secondary base repeater node (not shown in **FIG. 1**) configured to transmit to any of three adjacent picocells **102**. The fact that the

15 picocells **102** are angled with respect to the central transmission direction of a base station **106** is indicative of the fact that in the case shown in **FIG. 1**, at each secondary base repeater node, one or a combination of the three possible transmission directions are used for the re-transmission of the information signal. The base station **106** in this case acts both as an originating information signal source and as an originating base station for
20 transmitting a command signal. The command signal is a narrowband signal which can be transmitted on a channel with a great enough range to reach the entire megacell. The information signal is a high speed (high bit-rate/broadband) signal with a short range

picocell, which is transmitted from a secondary base repeater node to its adjacent neighbors.

Another embodiment of the present invention is presented in **FIG. 2**, wherein a fan-out tree structure is depicted, along with an information signal output end receiver and a loop back means. The fan-out tree structure **200** is shown as a plurality of potential paths **202** through the megacell **204**. A base station **206** is positioned at an input end **208** of the fan-out tree structure **200**, and an information signal output end receiver **210** is positioned at an output end **212** of the fan-out tree structure **200**. The information signal output end receiver **210** is designed and positioned such that it is capable of receiving the information signal from all of the secondary base repeater nodes at the output end **212** of the fan-out tree structure. Additionally, a loop back means **214** is provided connecting the information signal output end receiver **210** with the base station **206** in order to loop back the information signal. The information signal output end receiver **210** may be a single antenna or a plurality of antennas. The loop back means **214** may be a wired connection (metal wire or fiber-optic cable), or it may be a point-to-point RF and optical wireless signal such as a laser (a free-space optical wireless connection) or millimeter-wave RF broadband connection.

Using the configuration depicted in **FIG. 2**, it is possible for a user within one picocell to communicate with a user in another picocell via the loop back means **214**. A database of all control codes for controlling the direction of transmission of the information signal from each secondary base repeater node is used to generate routes for the information

signal through the plurality of secondary base repeater nodes. Additionally, the information signal may be modified as it is re-transmitted through the plurality of secondary base repeater nodes, typically to inform the base station **206** of the current location of each user within the megacell. Using a lookup table along with the proper command codes from the database, it is possible to route a call from one user to another user in the megacell using the loop back means **214** for communication to create a ring-like structure. Thus calls may be set up and routed through the plurality of secondary base repeater nodes in the megacell. The information signal may also include a portion set aside specifically for call routing and other information included by modification or supplementation at the secondary base repeater nodes. In order to set up calls, the secondary base repeater nodes may be configured to receive and re-transmit call setup requests from users local to the secondary base repeater nodes. The call setup requests typically include an identity of a target user (which may be in the form of a code such as a telephone number), with the identity being used for mapping the identity of the target user to a picocell within the megacell, and for providing information necessary for generating a direction command for a command signal to cause the call to be established along a predetermined path through the megacell **204** and the loop back means **214**. Thus, a user may set up a call to transmit information to another user within the megacell **204**.

In addition to being used for setting up calls, the loop back means **214** may also be used for testing paths and diagnosing problems within the network. For example, occasionally, an information signal can be directed through every path in the network in

order to ensure that the information signal is properly received back at the base station
206. In this way, the integrity of each connection within the network may be tested for
diagnosis.

5 A more detailed view of the components of a secondary base repeater node is depicted in
FIG. 3. Each secondary base repeater node **300** includes an information signal receiving
antenna **302** for receiving an information signal from an information signal source or
from another secondary base repeater node **300**. The information signal receiving
antenna **302** may be configured to receive in any broadband channel suitable for the
10 particular embodiment. An amplifying means **304** is connected with the information
signal receiving antenna **302** for receiving the information signal and for amplifying the
signal for re-transmission. Note that the secondary base repeater nodes **300** are
preferably positioned near the edge of (and within) the coverage range of the secondary
repeater node **300** from which it receives (near the edge of the picocell). This facilitates
15 the most efficient use of the secondary base repeater nodes **300** for area coverage. In
greater detail, the amplifying means **304** may be a multistage amplifying system
comprising a common amplifier **306** for initially amplifying the information signal before
it is split in a three-way splitter **308**. After the information signal has been split, it is
passed to a switch bank **310**, typically in the form of three independently addressable
20 switches controlled by a signal from the control signal receiver **312**. Assuming a
particular switch **314** in the switch bank **310** is activated by the control signal, the
information signal is passed through the switch **314** and is then amplified by a branch
amplifier **316** in preparation for transmission by the three-directional information signal

transmitting antenna **318** in at least one of three directions, if the node is commanded to be part of a path setup. Note that the branch amplifiers **316** are positioned after the switch **314** in order to conserve power so that the amplifier and information signal portions not intended for transmission are not activated and amplified.

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The three-directional information signal transmitting antenna **318** is preferably in the form of either a sector antenna or a multi-beam forming antenna array in the RF or optical domain, but can be of any form useful for a particular embodiment. Further, the three-directional information signal transmitting antenna **318** is preferably operative to transmit in at least one of three approximately 60 degree sectors such that the 60 degree sectors slightly overlap and add up to provide a 180 degree angular coverage region substantially opposite the information receiving antenna **302**. Greater detail as to the control of the switch bank **310** will now be presented.

15 The command signal is preferably transmitted in the form of an amplitude-modulated frequency shift keyed (A-FSK) signal including digital binary (two-bit) format direction command segments, the aggregate of which are collected in a register for assembling a direction command to match the node switching codes for directing the three-directional information signal transmitting antenna **318**. In order to generate a command signal, the system first looks up the switching control codes for the switches **314** of the secondary base repeater nodes **300** along a desired path through the megacell. The selected switching control codes are then used to generate a command signal, which is transmitted two bits at a time in command segments using an amplitude-modulated frequency shift

keying scheme. The command signal code bits are then received, two bits at a time, and are re-assembled in a register at the secondary base repeater nodes 300. A switch processor is then used at each secondary base repeater node 300 to compare the command signal with the command codes for the on-board switches 314 in order to determine whether to re-transmit the information signal. By using an amplitude-modulated frequency shift keying technique, only signal envelope detection is required, eliminating the need for RF mixing and filtering circuitry.

A block diagram of an A-FSK modulator is depicted in FIG. 4(a) for greater clarity.

Sinusoidal waves of two frequencies, f1 400 and f2 402 are used in conjunction with a two bit register 404, three switches 406, a multiplier 408, an inverter 410, and a multiplier factor 412 in order to generate an amplitude modulated frequency shift keyed signal as depicted in FIG. 4(c).

A block diagram of an A-FSK demodulator is depicted in FIG. 4(b) for greater clarity.

The A-FSK demodulator receives input from the command signal receiving antenna and uses frequency filters 450 to separate the signal into two frequencies, f1 and f2.

Envelope detectors 452 are then applied to the signal in order to detect the amplitude of the command signal. A comparator 454 is used to determine which bit of a two-bit

register 456 to set first (in the Y position). A summer 458 and a decision maker 460 are used to determine which bit to set next (in the X position). After the bits in the register have been set, they are ANDed in an AND gate 462 with the control codes 464 for the

three-directional information signal transmitter in order to determine in which direction (if any) to re-transmit the information signal.

Note, once again, that by using the A-FSK modulator and demodulator as depicted in

5 **FIG. 4(a)** and **FIG. 4(b)**, respectively to provide switch processing, a digital wireless signal may be detected in a digital format without the need for local oscillator mixing and radio frequency processing. Further note that A-FSK is a well-known technique, so detailed discussion of A-FSK is intentionally limited herein. Further information on A-FSK techniques is available in "Amplitude-Frequency Shift Keying (AFSK)" by Sanjal
10 Kumar Das of Lucent Technologies (India), Ltd., Bangalore, India in BWAS, conference digest pp. 237-240, 4 December, 2000, San Francisco, CA, USA, wholly incorporated herein by reference.

A block diagram depicting the functional components of an originating base station is
15 depicted in **FIG. 5**. As shown, the originating base station **500** includes a code generating transmission unit including a direction code database **502**, which stores direction codes for each one of the plurality of switches controlling three-directional information signal transmitting antennas within the plurality of secondary base repeater nodes. The codes stored in the direction code database **502** are retrieved and used by a
20 processor **504** in order to cause the secondary base repeater nodes to transmit the information signal along a desired path through the megacell. A modulator **506** is included for receiving the digital direction codes and modulating them onto a radio frequency channel to produce a command signal. Preferably, the modulator **506** uses an

amplitude-modulated frequency shift keying scheme. After modulation, the command signal is transmitted across the megacell by a command signal transmitter **508**. As shown, the originating base station **500** also includes an information input **510** for receiving information from an information source. The information from the information input **510** is transmitted across a picocell to a secondary base repeater node by an information source transmitter **512**. The information source transmitter **512** operates using a broadband channel, and the command signal transmitter **508** operates using a narrowband channel.

In another embodiment, the present invention comprises a method for distributing information to selective picocells within a megacell by using a networked and field addressable distributed antenna system. A block diagram outlining the steps of the method of the present invention is provided in **FIG. 6**. An information signal is received at a secondary base repeater node from an information source (possibly an originating base station) in an information signal receiving step **600**. A command signal is also received, including a direction command, from a command signal transmitter in a command signal receiving step **602**. The command signal is then used to determine at least one direction in which to re-transmit the received information signal from the secondary base repeater node in direction determining step **604**. Once the transmission direction(s) have been determined, the information signal is re-transmitted in at least one of three directions as determined in the direction determining step **604** in an information signal re-transmitting step **606**. In this manner, the information signal may be propagated through the plurality of secondary base repeater nodes in the megacell.

An optional step (not shown) of configuring the secondary base repeater nodes may be provided to enable the nodes to re-broadcast the information signal in a fan-out tree structure. Furthermore, the secondary base repeater nodes may be positioned such that only desired picocells within the megacell are capable of receiving the information signal. Also, as discussed relative to the antenna system previously, the megacell may have a designated input end and an output end, and the method may further comprise the step of looping back the information signal 610 from the output end to the input end. The looping back step 610 may be supplemented by providing an optional and additional step of modifying the received information signal 608 at each secondary base repeater node prior to the information signal re-transmitting step 606. Further, the looping back step 610 provides the groundwork for the additional step of setting up a call between users in the megacell, and may also be used as the basis for providing a step of using the looping back of the information signal for diagnostically ensuring correct path setup and for checking connection integrity within the megacell.

Thus, the present invention provides a means for selectively illuminating areas of a megacell with an information signal on a broadband channel. The present invention is easily scalable, as secondary base repeater nodes may be added or subtracted, and the database of codes may be modified, to alter the coverage area in order avoid useless or undesired illumination of particular areas (e.g., areas that are unpopulated with users). Although the individual secondary base repeater nodes typically communicate the information signal in a line-of-sight transmission medium, in aggregate, they can provide

for non-line-of-sight communication with respect to the originating information source by allowing the information signal to “hop” around obstacles.